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Research, part of a Special Feature on Traditional Ecological Knowledge and Global Environmental Change: North and South Perspectives

Local Perceptions of Climate Variability and Change in Tropical Forests of Papua, Indonesia

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ABSTRACT. People everywhere experience changes and events that impact their lives. Knowing how they perceive, react, and adapt to climatic changes and events is helpful in developing strategies to support adaptation to climate change. Mamberamo in Papua, Indonesia, is a sparsely populated watershed of 7.8 million hectares possessing rich tropical forests. Our study compares scientific and traditional ecological knowledge (TEK) on climate, and analyzes how local people in Mamberamo perceive and react to climatic variations. We compared meteorological data for the region with local views gathered through focus group discussions and interviews in six villages. We explored the local significance of seasonality, climate variability, and climate change. Mamberamo is subject to strikingly low levels of climatic variation; nonetheless local people highlighted certain problematic climate-related events such as floods and droughts. As our results illustrate, the implications vary markedly among villages. People currently consider climate variation to have little impact on their livelihoods when contrasted with other factors, e.g., logging, mining, infrastructure development, and political decentralization. Nonetheless, increased salinity of water supplies, crop loss due to floods, and reduced hunting success are concerns in specific villages. To gain local engagement, adaptation strategies should initially focus on factors that local people already judge important. Based on our results we demonstrate that TEK, and an assessment of local needs and concerns, provide practical insights for the development and promotion of locally relevant adaptation strategies. These insights offer a foundation for further engagement.

Key Words: *adaptive strategy; coping mechanism; deforestation; ecosystem services; gender; seasonality; traditional ecological knowledge*

INTRODUCTION

People who depend on natural resources, especially the poorest, are often particularly vulnerable to climate variability and change (Morton 2007). We need to understand how people experience and respond to such variability to guide climate change adaptation strategies. Rural societies already have in-depth knowledge of local climate variability and change as part of their traditional ecological knowledge (TEK), i.e., their knowledge, acquired and transferred through generations (Berkes et al. 1995, 2000). Here "local perceptions" refers to the way local people identify and interpret observations and concepts (Byg and Salick 2009, Vignola et al. 2010). Even though climate change may bring conditions beyond previous experience, local knowledge and perceptions remain the foundation for any local response.

Most studies on perceptions of climate deal with temperature and rainfall, i.e., amount, annual distribution, start and end dates (Deressa et al. 2009, Fisher et al. 2010). Meteorological data are often used to confirm villagers' assessments (Orlove et al. 2000, Vedwan and Rhoades 2001, Deressa et al. 2009, Fisher et al. 2010) or refute them (Maddison 2007, Bandyopadhyay et al. 2011 for long-term perceptions). Previous studies have dealt with perceptions of seasonality (Bryan et al. 2009, Bandyopadhyay et al. 2011), perceptions of risks and threats related to climate variability (Grothmann and Patt 2005, Thomas et al. 2007, Adger et al. 2009, McCarthy 2011, Saroar and Routray 2012) and local knowledge in forecasting weather and adapting to climate (Orlove et al. 2000). Some authors highlight the need to consider climate in a wider context, such as health or policies (Mubaya et al. 2012, Shackleton and Shackleton 2012), and emphasize the importance of these broader interactions when developing adaptation projects and policies (Reid and Vogel 2006, O'Brien et al. 2009); this is also our approach.

Our aim is to examine how local knowledge can be used to inform and thus improve projects and policies for adaptation to climate change. This work is unusual in examining remote tropical forest communities. We contrast scientific and local knowledge about different aspects of climatic variation: seasonality, climate variability, and climate change in six villages in Mamberamo, a forested area in Papua, Indonesian New Guinea. We are particularly concerned with how these variations may have caused problems or hardships, what the responses and constraints have been, and what can be learned from these that may assist in future adaptation. Seasonality is the cycle of conditions seen over a year when long-term records are averaged and climate variability is the deviation from the average. We focus on interannual variability, i.e., how temperature or precipitation changes from one year to another, including extreme events such as drought or heat

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waves. Climate change involves longer term trends, from decades to centuries.

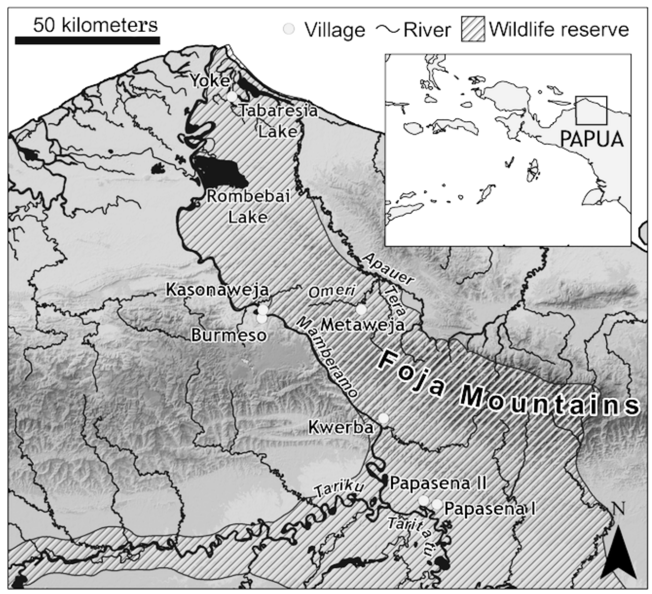
We consider two different categories of local responses to climatic variations: coping and adaptive responses. The difference between them has been widely discussed in the literature on development, food security, and, more recently, climate change (Davies 1993, Roncoli et al. 2001, Berkes and Jolly 2002, Eriksen et al. 2005, Smit and Wandel 2006, Fabricius et al. 2007, Eriksen and Silva 2009, Ravera et al. 2011, Brockhaus et al. 2013). Coping responses or mechanisms are unplanned, reactive, and short-term responses to immediate threats, whereas adaptive responses or strategies refer to proactive and anticipatory changes over long periods to reduce the impacts of recurrent threats or gradual changes (Davies 1993, Berkes and Jolly 2002). The dichotomy between short-term and long-term activities is seldom clear because short-term activities affect, and depend on, long-term ones. For example, households may prioritize their strategies to stabilize future incomes over their immediate needs (Eriksen and Silva 2009). In addition, Davies (1993) differentiates coping mechanisms, which do not modify prevailing systems (e.g., production systems, social or economic structures), and adaptation, which implies changes in rule systems or the moral economy. Coping mechanisms can also be anticipatory. For example, Cooper et al. (2008) consider diversified cropping in which failure of any one is tolerable and failure of all is unlikely. Coping mechanisms are developed by individuals or households and adaptive strategies occur at the community level or above (Berkes and Jolly 2002, Osbahr et al. 2008).

In the context of a broader multifaceted study on natural resource management, we researched how people perceive climate variations and their impacts. Specifically, we compared scientific data and local perceptions of climate seasonality, variability, and change. We characterized what past climatic events people recognized and how these had impacted people’s lives, and how people had adapted and identified associated constraints. We also assessed perceptions of other nonclimatic events threatening local livelihoods and the forests on which people depend. We discuss how scientific and local perceptions can be combined to inform and improve adaptation programs and policies.

STUDY SITE

Mamberamo is located in the Indonesian province of Papua. The watershed covers 78,000 km² and is dominated by three major rivers: the Tariku (or Rouffaer) and Taritatu (or Idenburg) rivers that join the Mamberamo River (Fig. 1). The 20,000 km² Mamberamo-Foja Wildlife Reserve is located in the southern and eastern parts of the watershed. Mamberamo Raya is a new 31,000 km² regency, i.e., a political subdivision of the province, administered by an elected head and local parliament. The population density is less than 1 inhabitant per square kilometer. Approximately 23,000 people live in 59 villages, most of which are located along the major rivers. Because there are no paved roads, settlements are accessed via waterways, trails, and small airstrips. Ecosystems in Mamberamo are mostly relatively undisturbed natural forests in swamps, lowlands, hills, and mountains, and riparian areas. The rich fauna and flora remain little studied (De Fretes 2007, Polhemus and Allen 2007, Johns et al. 2007, van Heist et al. 2010).

Fig. 1. Map of Mamberamo watershed and the surveyed villages (Kwerba, Burmeso, Metaweja, Yoke, Papasena 1 and 2).



Based on our knowledge of the region and a cluster analysis of 40 villages with existing data, i.e., on topography, ecosystems, population density, distance to market and services, and official zoning, we identified five groups of village types. These groups were called, in short: swamps, accessible hills in protected forests, accessible production forests, remote hills in protected forests, and coasts. We selected one village randomly in each group, but in one location (Papasena) the people insisted on differentiating between two villages (Papasena 1 & 2) and we finally worked in a total of six villages: Papasena 1 & 2 (hereafter referred to as Papasena), Kwerba, Burmeso, Metaweja, and Yoke (Table 1). Although these villages are separated from each other by less than 200 km, differences in elevation and wind exposure account for differences in local climates, for example, temperature and orographic precipitation. Burmeso has the largest population (145 households) and Metaweja the smallest (44 households). Common cultural traits are shared by the different local communities, such as similar taboos, sacred sites, and rituals (De Vries 1988, Oosterwal 2007).

Table 1. Description of the surveyed villages. The column 'area' is for customary land.

Name	Area (km²)	Main ecosystems	Status of the surrounding forest	Main livelihoods	Important vegetal resources:	Important animal resources
Papasena 1 & 2	1700	Permanent and semipermanent swamp forests, hill and mountain forests	Protected area	Fishing, wild and planted sago exploitation, hunting, home garden cultivation (banana, red pandanus, betel).	Sago, Fijian longan, and a lot of wild fruits	Freshwater fish, crocodiles, wild pigs, birds of Paradise, cassowaries, cockatoos, hornbills, maleo
Kwerba	1100	Hill and mountain forests	Protected area	Wild and planted sago exploitation, hunting, home garden cultivation (banana, sweet potato, cassava, red pandanus, betel).	Sago, Dipterocarps, Fijian longan, iron wood	Crocodiles, freshwater fish, wild pigs, birds of Paradise, cassowaries, cockatoos, hornbills, maleo
Burmeso (future capital of the regency)	1500	Lowland and hill forests	Production forest, degraded because of logging activities.	Fishing, planted sago exploitation, hunting, home garden cultivation (cocoa, banana, sweet potato, red pandanus, betel).	Sago, Iron wood, Fijian longan, Agathis	Wild pigs, cassowaries, phalangers, birds of Paradise, freshwater fish.
Metaweja	300	Hill, mountain and riparian forests on steep slopes	Protected area	Wild and planted sago exploitation, hunting, home garden cultivation (banana, sweet potato, cassava, betel).	Sago, Agathis, Fijian longan, iron wood.	Wild pigs, cassowaries, birds of paradise, crowned pigeons.
Yoke	1400	Swamp forest, lakes, and mangrove	Protected area	Fishing, wild and planted sago exploitation, coconut planting, cocoa planting, hunting, home gardens with betel, cassava, banana.	Sago, Watercress, Fijian longan, salty-leaf trees	Salt and fresh water fish, molluscs, crustaceans, crocodiles, wild pigs, cassowaries.

Local livelihoods vary according to ecological factors, e.g., topography and the ecosystems in which villages are located. However, people in all the villages rely on fishing, hunting, and the collection of various forest products, including sago (*Metroxylon sagu*). Vegetables are cultivated close to settlements and camps.

METHODS

This research was built on a broader multidisciplinary study on land-use planning and natural resource management, originally developed for studying the importance of biodiversity and landscapes for local people (Sheil et al. 2002). Our research used focus group discussions, household interviews, and climate data analysis.

Most young men in these communities are fluent in Indonesian, and most other people have at least a reasonable working knowledge of the language. Thus we were able to perform most of our interviews in Indonesian, but in some cases, e.g., talking with some elders, men or women, we used local translators; all villages had people able to play this role. Not all respondents were literate, but the facilitator ensured that literacy was not necessary. An important question was whether local people make strict use of the conventional western calendar. Based on our discussions with them over many months of fieldwork, we are confident that they do. This reflects their education, the influence of the church and church calendar events, and other official schedules.

Focus group discussions

Semistructured questionnaires were used with four groups of villagers defined by gender and age in each village: young (less than 30 years old) men, young women, mature men, and mature women. We worked with a total of 23 groups; insufficient young women were present in Papasena 2 at the time of the survey so this group was omitted. During our discussions with villagers, we used "seasons" (*musim*) rather than "climate" (*iklim*). We discussed "normal seasons" (*musim biasa*), i.e., weather people expect during a normal year, and "abnormal seasons" (*musim tidak biasa*), i.e., seasonal patterns that differ from a normal year and that can occur every several years or exceptionally. We explained extreme climatic events as "unexpected seasons" (*keadaan musim yang luar biasa*), to distinguish them from nonclimatic natural disasters. We discussed how "abnormal seasons" had changed. We asked how variability and change had impacted them, for example, their gardens, health, or physical assets, and how they had responded, e.g., moving away or asking for government aid. To address climate change issues, we only asked the groups how they perceived climate (using the term *musim*) would be in the future. The groups were not presented any scenario of global climate change, i.e., scenarios developed by climate modelers, contrary to other studies in which climate scenarios are used to analyze future vulnerability with local stakeholders (Ravera et al. 2011).

Interviews

Household surveys were conducted in parallel with the focus group discussions in 30% of the households and in at least 30 households when villages had less than 90 households. Forty-four households were surveyed in Burmeso, and 30 in each of the other villages, with a total of 164. In each village, a quick survey was first conducted in all the households with simple questions, i.e., respondent's name, family members, clan, and ethnic group. The name of each household was put in a bag and we randomly withdrew names for a more detailed survey. If a selected household was absent, we picked a new name from the bag. We then asked the age of each member of the household, level of education, main occupation, and secondary occupation. We conducted semistructured interviews with heads of households, some of them being women, about local perceptions of threats to natural resources (e.g., what factors influenced forest cover or water), and to people's livelihoods, (e.g., what factors influenced changes in cultivation and settlement areas). During the interviews we let the villagers talk about any perceived threat, for example, private companies, diseases, unsustainable extractive activities, and landslides. Threat was defined as an external phenomenon that can potentially negatively impact people's livelihoods and natural resources. We asked people to rank threats according to their perceived impact and frequency. We organized the responses in categories during the data analysis.

Data analysis

In each village, the four group discussions resulted in different views on seasonality, variability, and change. A month was considered as "wet" ("dry") in the village if three or more groups perceived it as "wet" ("dry"; two or more groups in the case of Papasena 2 where there were only three groups). Qualitative data from focus group discussions were processed with MaxQDA software, to organize and cluster them based on keywords (MAX Qualitative Data Analysis version 2, 2007). For quantitative data from the demographic survey (i.e., age, education, job of each member of the households) and household surveys (i.e., perceived importance of the forest for local livelihoods, perceived threats to the forest and local people) we used cross tabulation with Chi Square (SPSS version 17, 2008).

Climatic data

We searched for local climate data, but the only local weather station, belonging to the logging company PT Mamberamo Alas Mandiri, provided only three years of observations (2009-2011), too few for analysis of variability or trends. We searched global climatic databases for information on mean climate, past time-series, and future climate scenarios. Because of the coarse spatial resolution of some datasets (e.g., 0.5 arc-degree or around 50 km), data were selected for a single point inside our study area using the coordinates: 2.30° S and 138.03°W. For datasets with a finer resolution (e.g., 2.5 arc-minutes or 5 km), we retrieved the information specific to the six villages. For each village we compared meteorological data with local perceptions of seasonality, climate variability, and future climate change, looking for agreement or discrepancy.

For the mean climate, we used the WorldClimCL25 dataset, which provides the average monthly temperature and precipitation over the 1950 to 2000 period. Data from weather stations are spatially interpolated at a resolution of 2.5 arc-minutes or 5 km (Hijmans et al. 2005). To analyze the seasonality of an average year, we differentiated wet months (at least 5% more rainfall than the monthly average), dry (at least 5% less rainfall than the monthly average), and average (within 5%). Before choosing this 5% value for the threshold, we tested several other values, i.e., higher values resulting in less months identified as dry or wet, but with similar distribution of dry and wet seasons within the year. We chose the 5% threshold because it resulted in a similar number of wet and dry months according to local perceptions and climate data.

For the temperature and precipitation time series from 1960 to 2009, we used the CRUTS3.1 dataset, which is based on interpolation of weather station data and has a resolution of 0.5 arc-degree or 50 km (Mitchell and Jones 2005). This dataset was selected because it is the most frequently used dataset in agricultural studies (Ramirez-Villegas and Challinor 2012). We extracted climate data for our study site, but the validity of these data is questionable because they are interpolated from sparse climate records: in a 10°x10° square (around 1000 km x 1000 km) centered on Mamberamo, the CRUTS3.1 dataset references only 11 stations.

With the CRUTS3.1 dataset, we also compared the seasonality of an average year and the interannual variability of time series between our site and sites with similar climates (within 10% of the mean annual precipitation and 1 degree of the mean annual temperature). To indicate the future climate, we used scenario data from the TYNSC2.0 dataset (Mitchell et al. 2004). The 16 scenarios of this dataset represent the possible future climate in a grid with a resolution of 0.5 arc-degree. The scenarios were developed with four scenarios of global greenhouse gas emissions, coupled with four different models of the global climate system to predict how climatic variables could possibly evolve in space and time.

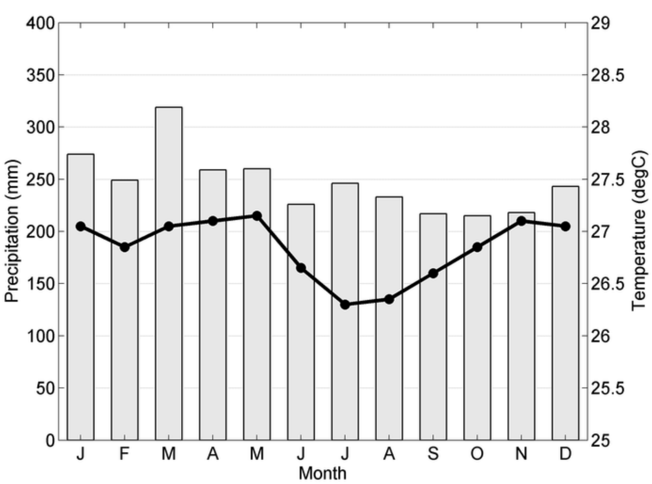
RESULTS

Seasonality in Mamberamo according to different perspectives

From meteorological records

Records show that Mamberamo experiences only minor seasonality (Fig. 2) with monthly precipitation from 215 to 319 mm in an average year. Around 97% of the total area of the world with similar climates, for example in the Amazon, the Philippines, Sumatra, and Borneo, has a higher intra-annual range of precipitation, i.e., higher seasonality. Similarly, monthly temperature varies from 26.3° to 27.1°C and 97% of the global sites with similar climates experience a higher intra-annual range of temperature.

Fig. 2. Monthly mean temperatures and precipitation in Mamberamo based on WorldClimCL25 dataset (Hijmans et al. 2005).



According to local perceptions

In the six villages, people perceived the principal seasons somewhat differently (Table 2). For example, in Papasena one dry season was perceived to be from July to September and in Kwerba from August to December. In Metaweja and Kwerba, two dry seasons were perceived. In the coastal village of Yoke, the dry season was perceived as the longest of the six villages.

Villagers from Yoke noted how the wet season is associated with winds from the west and large waves and tides, whereas the dry season is associated with winds from the east and smaller waves and tides. Wind, tides, and waves affect activities such as fishing.

In Papasena and Kwerba, during the dry season, crocodiles are hunted because they are more visible on the riverbanks when the water is low. This is also the season that land is cleared for new gardens, but crops are planted in all the villages in the wet season utilizing the rain and river for watering. Most other activities, such as sago harvesting, occur all year round. In general, villagers reported that they make decisions regarding fishing, hunting, or preparing and planting gardens based on their experiences and perceptions. They plant their vegetables during the wet season, but they need dry days to prepare the land. They decide when to plant their gardens based on the rain. They also pay attention to heavy rains for fear of flash floods.

Table 2. Seasonality perceived in the surveyed villages (focus group discussions with women, young and mature, and men, young and mature) and analyzed with WorldClimCL25 (Hijmans et al. 2005). Note: black = wet month, grey = dry month, white = unclear or average.

		J	F	M	A	M	J	J	A	S	O	N	D
Papasena	Perception												
	Climate Data												
Kwerba	Perception												
	Climate Data												
Burmeso	Perception												
	Climate Data												
Metaweja	Perception												
	Climate Data												
Yoke	Perception												
	Climate Data												

Comparisons between local perceptions and meteorological records

Differences in seasons in the north of the watershed (Yoke), in the center (Burmeso, Metaweja), and in the south (Kwerba, Papasena) are revealed by the interpolated climate data and the results from group discussions (Table 2). The comparison of climate data with local perceptions of seasonality shows a good match in Papasena because both show a dry season from June or July to September or November. In Kwerba and Metaweja, the two dry seasons (February-March and August-December in Kwerba; and in March-May and September-October in Metaweja) perceived by local people do not appear in the climate data analysis; only one dry season was revealed in these two cases. In Burmeso and Yoke, the dry season appears later in the year in the climate data (August-November) than according to group discussions (June-August in Burmeso; April-September in Yoke).

Past climate variability and trends in Mamberamo according to different perspectives

From meteorological records

The interannual variability of recorded time-series is relatively minor. For annual precipitation the coefficient of variation (ratio of standard deviation and mean) is 12.0% between 1960 and 2009. Comparison with other climatically similar places in the world shows that 72% have a higher coefficient of variation. Similarly the standard deviation of annual temperature is 0.2°C between 1960 and 2009, which is lower

Table 3. Extreme events: recent occurrences and impacts according to focus group discussions in each village, with 4 separate groups of men, young and mature, and women, young and mature (combined summary). Dates in parentheses are years of events according to local people.

Name of village	Noticed extreme events	Impacts on villagers	Impacts on agriculture and natural resources
Papasena 1 & 2	Strong rains and floods (1998, 2009, 2010)	Malaria, influenza, headaches	Crops rot. Cassowary and wild pigs cannot find dry land.
	Long dry season and heat waves (2009)	Reduced drinking water	Sweet potato, cassava, sago affected. Fishes in the lakes die.
	Strong winds (not dated)	No impact	No impact
Kwerba	Heat wave and drought (1992, 1997, 2007, 2010)	Diarrhea	Crocodiles move from dry tributaries. Tree kangaroos, cassowaries, wild pigs move near rivers. Fishes and prawns die.
	Strong winds (2011)	Houses blown away or roof tiles blown off	No impact
	Long period of rain and floods (1996, 2005)	No impact	Sago, betel, taro, banana, wild pigs, crocodiles, fish affected.
Burmeso	Prolonged dry season and heat wave (1994)	No impact	Sago, annual plants, fishes, and wild pigs affected. Water in small streams gets warmer and dries up. Roads become dusty.
	Reversed seasons, irregular rains and floods (2009)	Influenza, malaria	No impact
Metaweja	Long rains and floods (1990, 2009 onward)	Diarrhea, influenza, malaria, houses damaged	Gardens damaged, dogs drowned.
	Strong winds (2008, 2011)	Houses damaged	Coconuts, breadfruit, betel, cocoa blown over.
	Long dry season (2009)	No impact	Fishes and prawns affected by water temperature.
Yoke	Long dry season (1994, 2003, 2010)	Crop failure, wells dry up or increase in salinity, no drinking water near the village	Crops affected (betel, bananas, gnemo, and sago). Freshwater fish die (saline water).
	Long rainy season (1997, 2001, 2011)	Diseases, mosquito infestation, strong tides disturb fishing activities	Crops fail, especially long cycle crops. Animals die in lowlands.
	Strong winds (2000, 2006, 2010)	No impact	Coconut trees, betel palm, and pine trees blown over.

than in 94% of places with similar climate. The range of annual mean temperature between 1960 and 2009 is around 1.2°C. Annual precipitation has not changed significantly over the 1960 to 2009 period. The annual temperature has increased significantly by 0.08°C per decade (95% confidence interval: 0.04-0.11) during this period, a smaller increase than the observed global trend of 0.128°C per decade over the same period (Trenberth et al. 2007).

According to local perceptions

People from the six villages do not keep a careful account of minor climatic variations, but they identified three types of extreme events related to climate variability in the last 10 years: droughts, floods, and strong winds. Notable events and their impacts differed among villages, but in general they affect health, e.g., malaria during longer wet seasons, or destroy crops (Table 3).

According to villagers located near the Mamberamo River (Burmeso, Kwerba, and Papasena), significant floods happen every five years or so and the last one occurred in 2009. In Yoke, people were less concerned about interannual variability than in other villages, in part because their coastal location appears less vulnerable to floods. In Metaweja, people reported whirlwinds occurring every year or two, with impacts on tree crops, e.g., betel, coconut, and sago, and buildings, roofs being especially vulnerable. Papasena villagers said exceptionally large floods have normally occurred about every 15 years. These floods have an impact on wildlife because pigs and cassowaries seek refuge on the higher ground far from the village.

When asked about recent climatic events, men and women emphasized different concerns in all the villages, except Kwerba (Table 4). The perceived events differed in their frequency and severity and men more often highlighted droughts whereas women more often referred to extended rains. In Kwerba, the principle difference was between generations. For older people, prolonged rains were of major concern, whereas youths put more emphasis on extended dry seasons.

People did not report changes in mean climate, but they did highlight a change in the frequency of various extreme events. Villagers from Papasena explained that damaging floods now occur at least every 5 years instead of 15 years apart, as in the past. Kwerba villagers also said extended rainy seasons are increasingly frequent. In Metaweja and Yoke, people said strong winds are now more common. Villagers in Burmeso and Yoke also felt extended dry seasons were becoming more frequent.

Table 4. Most frequent extreme events according to gender, based on focus group discussions in each village, with 4 separate groups of men, young and mature, and women, young and mature.

Village	Perception of seasonal events	
	Men	Women
Papasena 1 & 2	Prolonged dry seasons and strong winds	Prolonged rains
Kwerba[†]	No clear gender-specific differences	No clear gender-specific differences
Burmeso	Long droughts	Prolonged rains and floods
Metaweja	Floods	Strong winds (but reported responses to extreme events were about floods).
Yoke	Prolonged dry seasons and strong winds.	Prolonged rainy seasons (affecting long-term crops) and prolonged dry seasons (affecting short-term crops).

[†]There are age-specific differences in the perception: elders: prolonged rains and floods; youth: prolonged droughts.

Comparisons between local perceptions and meteorological records

In Burmeso, people reported reversed seasons in 2009 (the wet season was dry and vice-versa) and precipitation time-series confirms this observation. Rainfall during this dry season (June to August) was abnormally high (between 10% and 19% monthly, and 17% overall), whereas this wet season (October to December) was particularly dry (between 2% to 26% less rain monthly, and 10% less overall). The recorded drought at the end of 2009 also matched the perceptions of people in Papasena.

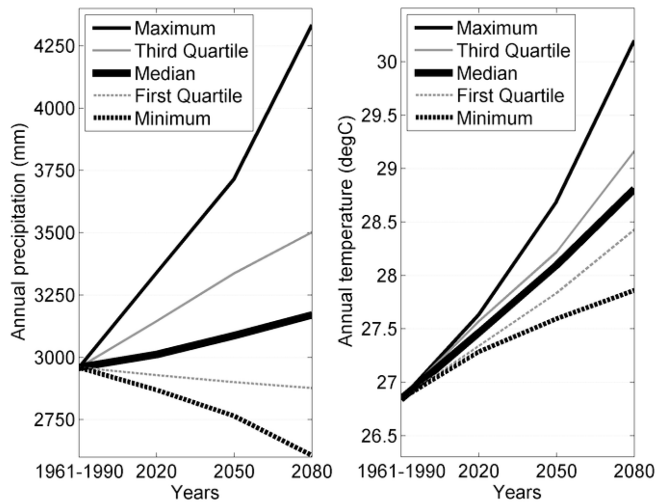
In the 1961 to 2009 period, monthly rainfalls higher than 420 mm occurred in 1969, 1970, 2005, 2007, and 2008 (420 mm is the 99% threshold we used to identify extreme events; higher monthly rainfalls occur on average only every 100 months or 8.3 years). The presence of three recent years in this list confirms the villagers' observations (extended rains in 2005, 2007, and 2008). However, it was not possible to compare perceptions and climate data about winds and short-term events, e.g., drought followed by heavy rain during the same month, which were not recorded in the monthly temperature and precipitation dataset.

Future changes in climate in Mamberamo according to different perspectives

From climate models

Out of the 16 climate scenarios we used, 12 predicted an increase in annual precipitation by 2080 (up to 1370 mm increase) and 4 predicted a decrease (up to 350 mm decrease). All scenarios predicted an increase in mean annual temperature with values ranging from +1.0 to 3.4°C by 2080 (Fig. 3). Twelve scenarios predicted that mean temperature will increase by more than one degree by 2050 compared with the period 1961-1990.

Fig. 3. Future change (minimum, quartiles, and maximum) in annual precipitation (left) and temperature (right), according to the 16 scenarios of the TYNSC2.0 dataset (Mitchell et al. 2004).



According to local perceptions

None of our respondents indicated any knowledge of international climate change concerns. When we asked our respondents about their perception of future trends in temperature and rainfall they replied that the current trends would continue or that they had no idea about future changes.

Adaptations to climate variability

Villagers reported different responses to climate variability (Table 5), but we did not note any marked difference in coping strategy by age or gender. Only in Yoke, men discussed the strategies for finding drinking water during long droughts, whereas women described the crops they plant in such situations. An anticipatory action to avoid flood damage was to locate gardens outside flood-prone areas, although issues regarding land rights sometimes encourage people to plant wherever they can, including on riverbanks, e.g., Burmeso, Kwerba, Papasena, Metaweja. In Papasena, villagers build their houses on stilts to avoid flood damage. In the event of a major flood, the people in Burmeso and Kwerba are always ready to move the village temporarily to higher grounds.

In contrast, people in Yoke are unwilling to move for political reasons. This community is divided into two settlements, but is considered as one village by the administration. The government suggested merging the two settlements and

Table 5. Coping and adapting strategies according to focus group discussions in each village, with four separate groups of men, young and mature, and women, young and mature (combined summary).

Village	Category of strategy	Strategies for flood	Strategies for drought
Papasena 1 & 2	Settlements	Build houses on higher stilts	No strategy
	Productive	Move gardens to higher ground. Hunt in areas not affected and near gardens where animals look for food. Plant fast growing crops and harvest before the rainy season (e.g., sweet potato and banana).	Plant cassava, which can grow in dry conditions
Kwerba	Settlements	Relocate temporarily to higher ground.	Replace roof tiles with grass or Pandanus leaves for air circulation.
	Productive	Move gardens. Go back to old flooded gardens afterward. Same cultivars are used.	Fish more because fish is easier to catch in clearer water.
	Cultural	No strategy	Use rituals for calling rain.
Burmeso	Settlements	Relocate temporarily to higher ground.	Stay in the forest in small settlements shaded by trees.
	Productive	Plant only short-cycle crops (string beans, ground nuts, other green vegetables).	Use spades to break hard soil, but the techniques for cultivation remain the same.
Metaweja	Settlements	Relocate temporarily to higher ground.	No strategy
	Productive	Move gardens to higher ground. Harvest annual crops before rainy season. Look for new locations of natural fishponds when stream changes direction.	Gnemo trees (*Gnetum gnemon)* decreasing and replaced by fern leaves as wild vegetable for household consumption.
	Cultural	Taboos to prevent gardens from being planted in Nuari Mountain, (sacred area). In case of violation important floods may occur. Use taboos against planting near the river to avoid crop damage by flood (now no longer observed).	No strategy
Yoke	Settlements	Repair damaged houses with whole community (this applies to winds).	No strategy
	Productive	No specific action because gardens are not moved.	Look for drinking nonsalty water far from the village.

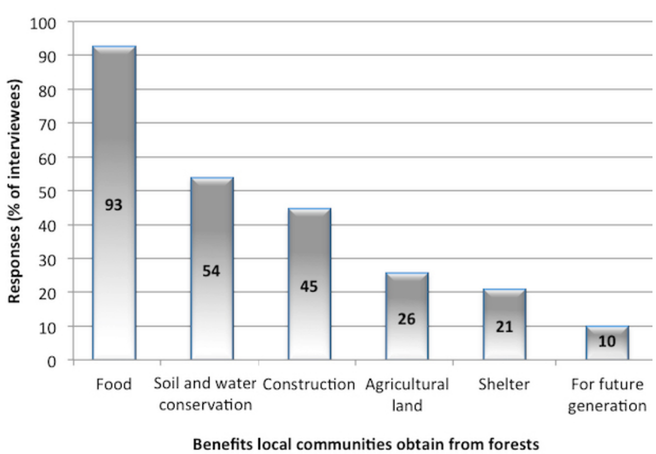
moving people far from the coast to avoid damage from tsunamis and erosion, which was rejected by villagers who want the two settlements to be recognized as separate entities.

Beyond climate: other perceived changes

In addition to the group discussions on climate, we also discussed the general changes that affect their landscapes and livelihoods. No one suggested that climate or climate related events would play a role in influencing their landscape. All villagers considered local forests vital to their livelihoods (Fig. 4) for food (wild sago, bush meat *gnetum*, leaves, and fruits), water (regulating water flow, preventing floods and erosion, and providing clean water), construction materials, agriculture, shelter, and as a reserve of products for future generations. In addition, forests were also important as sacred areas and for spiritual reasons. No significant difference was found between villages and respondents' gender.

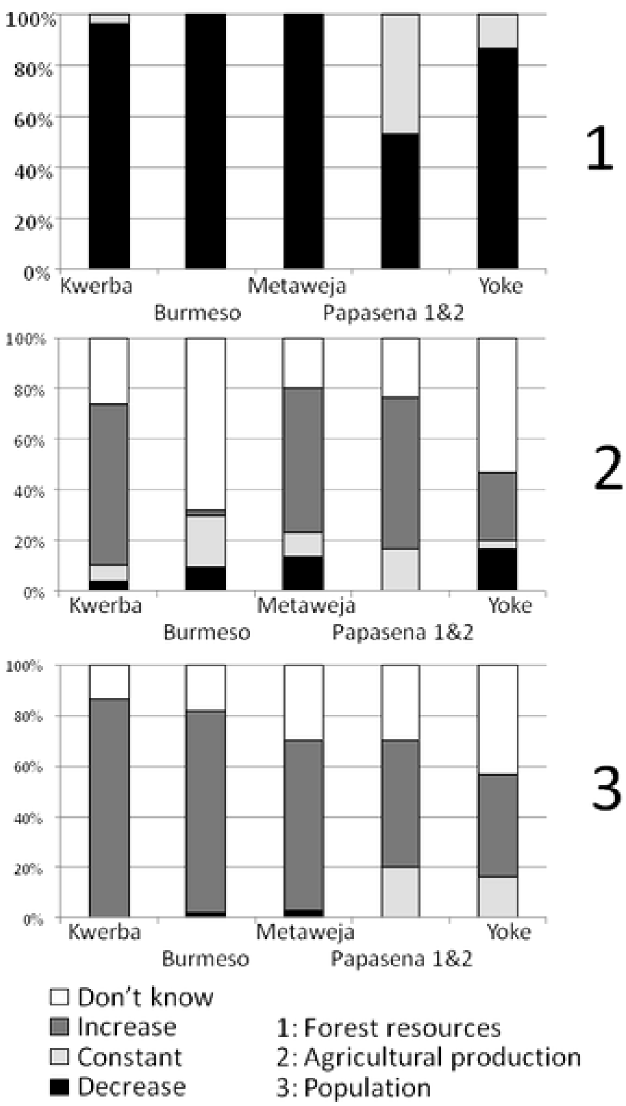
Most people believed that the area of forest will decrease in their territories in the future (Fig. 5). Villagers explained that their travels in the region and observations of other villages made them aware of the changes that may affect them. They believed that new settlements, land clearance for new gardens, infrastructure development, and private sector activities will reduce the forest area (Fig. 6). They foresaw an increase in mining or logging and industrial plantations. Some villagers in Papasena and Yoke thought the forest area will not change because they protect the forest themselves.

Fig. 4. Answers from 164 villagers in the surveyed villages when asked why forest is important to them. One respondent could provide more than one answer.



In the six villages, the main perceived reasons for forest loss were new settlements, infrastructure development, private sector activities, and agriculture expansion (Fig. 6). The main reason for forest loss was agriculture expansion in Kwerba, whereas it was infrastructure development in Metaweja (Fig. 6). In all villages but one (Burmeso), villagers believed their gardens will expand because of a growing human population. Villagers from Burmeso suggested that garden areas will actually decrease, because the village will become the regency capital, providing job opportunities and reducing the need for agriculture.

Fig. 5. Perceptions of the surveyed villages on changes in (1) forest resources, (2) agricultural production, and (3) population in the next decade, from a survey conducted in 164 households in 6 villages (Papasena 1 & 2, Kwerba, Burmeso, Metaweja, Yoke).



DISCUSSION

Differences in perceptions and strategies

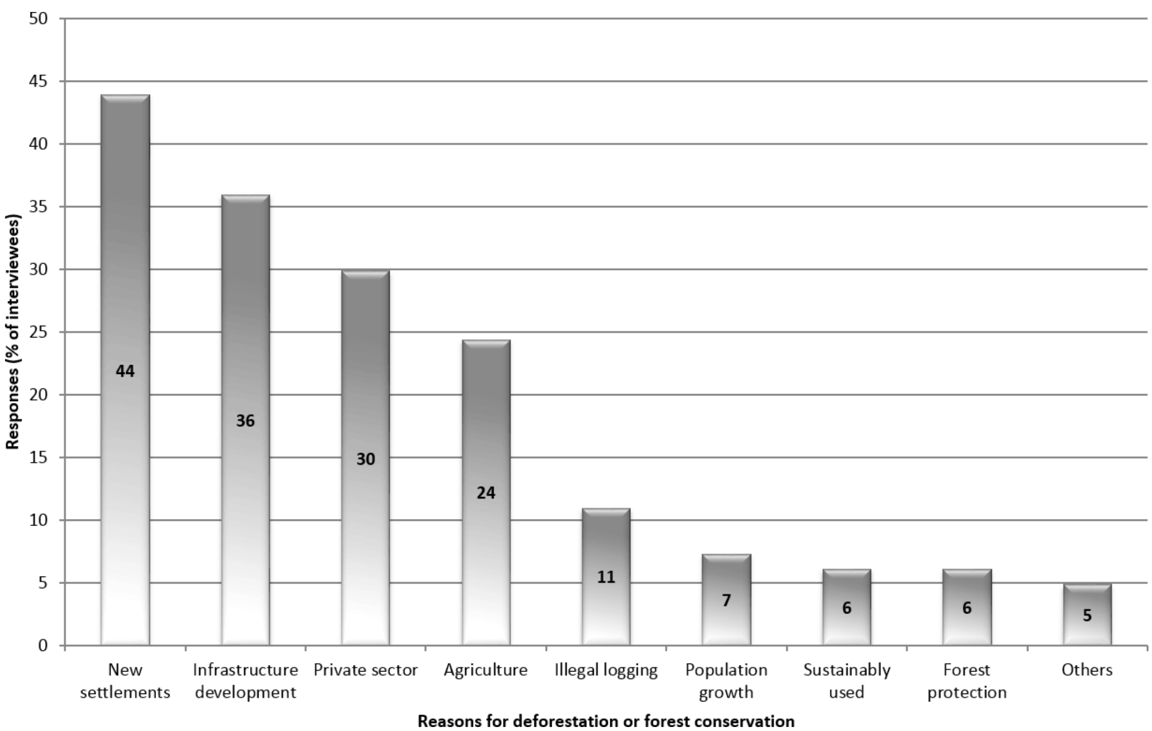
Our results show that local perceptions of seasonality and climate variability differ mainly according to village locations and the surrounding ecosystems, which determine local livelihoods. Some differences in perceptions were observed between gender and age groups, in relation to their different activities, their TEK, and experience about how their activities are affected by climate variations. For example, men understand better how events influence the availability of the wildlife they hunt in the forest, and women how cultivated areas are affected.

Even though different groups perceived climate variations differently, they shared some similar responses. For example, when threatened by flash floods, local people temporarily move to higher ground until the threat has gone. In general both men and women fish and share similar knowledge of where to fish after floods. All six villages have detailed knowledge of when and where to hunt when seasonal fruits are scarce and wild pigs difficult to find. The observed differences in responses can be explained by the agro-ecological conditions of each village, such as in the coastal village of Yoke where people have developed responses to the intrusion of salty water into wells.

Though elsewhere in Papua, local farmers are keen innovators in terms of adoption of new crops (Boissière and Purwanto 2007), local people in the six villages did not mention such innovation in the context of coping with climatic events as had been reported in other countries (Maddison 2007, Fisher et al. 2010). Rather, Mamberamo communities focused on the protection of their settlement (e.g., building houses on high stilts against floods) and mobility (e.g., moving to the forest during drought or changing fishing or hunting areas). Results showed that responses were not limited to settlements and productive activities; rituals are used, for example, revived taboos restrict gardening near the riverbanks. Some people considered the protection of sacred forests as a way to reduce floods. Comparable situations have been observed in Papua New Guinea (Jacka 2009).

Villagers almost never mentioned that they used more forest products when coping with extreme events, as has been observed elsewhere (Pramova et al. 2012). For example after a flood in Kalimantan, Indonesia, the most heavily affected, the poorest, and the least-educated people relied the most on forests for their coping strategies (Liswanti et al. 2011). In rural Peru, the gathering of forest products is an important strategy for coping with floods (Takasaki et al. 2004). This role of forests as safety nets does not appear in our case. It may be explained by the fact that forests are permanently used in livelihood activities, thus not mentioned as a coping strategy differing from business-as-usual. It may also reflect that the role of forest products was not a specific emphasis of our

Fig. 6. Answers from 164 villagers in the surveyed villages when asked the reasons for forest changes or nonchanges. One respondent could provide more than one answer. “Others” includes: erosion, trade, lack of forest rehabilitation, hydroelectric dam, and don’t know.



research questions. Additional research would be needed to better understand the links between forest products and coping with extreme events.

None of the reported strategies seem to have resulted from recent climatic events or perceived trends. In addition, the responses described by the villagers can be considered as coping mechanisms, either in anticipation or in reaction to threats, because they are short-term responses and do not imply changes in production or social systems (Davies 1993). Indeed local livelihoods are already adapted to the environment including normal climate variations and are thus robust under these conditions.

Comparing traditional ecological knowledge and climate data

Most studies on local perceptions of climate variability and change focus on how local people’s perceptions fit climate data (West and Vàsquez-León 2003, Gbetibouo 2009). Some authors encourage collaboration between scientists and indigenous people, but highlight the uncertainties and methodological challenges of eliciting local knowledge (Sheil and Lawrence 2004, Couzin 2007). Inconsistencies between local perceptions and biophysical data have generally raised concerns about the validity of local knowledge (Hansen et al. 2004, Sànchez-Cortés and Chavero 2011).

Although the patterns in some climate data matched the local perceptions of seasonality and variability reported by our informants, climate data must be considered with caution. In Mamberamo meteorological data has limited reliability and spatial resolution. These uncertainties limit our ability to make village centric assessments that take account of both actual and perceived local differences.

Limited climatic variation reduces people’s experience of change. Although it might be anticipated that people in such conditions might develop a highly nuanced appraisal of the small variations that do occur, this does not appear to be the case. More specifically the differences in the perceptions of seasons among groups, even within a single village, appear to reflect the limited seasonal variation upon which these judgments are based. This limited variation makes it difficult to identify clear dry and wet seasons from climate data as well as when discussing with villagers. The dichotomy between dry and wet seasons may have only limited local relevance and more complex or subtle seasonal patterns may be more significant, e.g., availability of certain fishes or fruits. One clear example of such seasonal perceptions was the significance of wind direction and strength reported in Yoke. The local reports of recent extreme events in Mamberamo were consistent among villagers and between perceptions and climate data. Local people mentioned trends such as more frequent droughts, floods, and whirlwinds. However, for cognitive reasons, people may interpret trends from a few recent events (Grothmann and Patt 2005). For example, two recent floods may create a feeling of increasing flood frequency even though floods occurred at similar, but irregular intervals in the past. Because neither climate data nor local perceptions can be considered as perfect sources of information, both can complement each other and provide valuable insights. However, when working in regions with few weather stations, local knowledge is a more detailed, and in many ways, more relevant source of information as long as it is considered with caution.

Implications for climate change adaptation

Understanding how local people experience climate variations and how they anticipate or react to them is likely to become crucial in the context of climate change. Given the low interannual climate variability in Mamberamo, sustained climate change will eventually create novel conditions for local people. Local people's farming behaviors are long established and thus well suited to the low interannual climate variability that prevails in this region. Some practices, such as mixed cropping and dispersal of sago and other crops in different locations, may provide some resilience. To spur larger scale adaptations may require climatic events to cross some threshold, e.g., frequent or marked floods or droughts that impact local crops and livelihoods. For example, with one degree of temperature increase (the third quartile of temperature increases in 2050 for the considered scenarios, see Fig. 3), 98% of the annual mean temperatures would be higher than the maximum annual mean temperature experienced in the past 50 years, assuming that the variations of annual temperatures around the mean is similar in the past and the future. The uncertainty of future precipitation has important local implications. For example, drier and wetter climates would have different consequences in different locations. In the hills and mountains, such as in Metaweja, people would be more affected by drier climates because the small rivers would dry up, as reported in the drought of 1997. In the swamps, such as in Papasena, larger floods might even submerge land areas that currently are always above water level.

None of the informants predicted major changes in Mamberamo's climate in the next 10 or 20 years. Their focus was on interannual variability and current trends from what they had experienced (more frequent droughts, floods and whirlwinds). We can anticipate how people may adapt to climate change by looking at their coping strategies in situations of climate variability and extreme climatic events. Local responses imply different mechanisms such as the temporary migration of villages or displacement of cultivation areas, the use of crops that can better resist climate change, and the solicitation of networks for help in a crisis. However, with climate change, current strategies may not be effective enough and new or improved responses may be needed. External interventions will probably address climate change adaptation in the future, e.g., external aid could increase with climate change, but not all interventions are good for adaptation (Eriksen et al. 2011).

External interventions for facilitating local adaptation to climate change are more likely to be successful if they build on existing knowledge, strategies, and traditions. For example, in Metaweja, traditional rules are used by the community to prevent villagers from cultivating gardens on the flood-prone riverbanks. These rules could be used in community-based adaptation plans, after people agree collectively on where to restrict cultivation.

Local knowledge can also help identify potential maladaptation, i.e., "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neill 2010:211). In the coastal village of Yoke, droughts increase salinity of the freshwater supply. Government interventions have caused the destruction of coastal vegetation such as coconut trees for building concrete houses along the shoreline to encourage villagers to move from their over-the-water houses. According to villagers, this has increased shoreline erosion and aggravated the problem of salinity in inland wells. Even though building concrete houses can be seen as an adaptation option, the associated removal of vegetation can result in maladaptation.

One commonly suggested adaptation option is to resettle villages located in disaster-prone areas. However, previous experience with resettlement has not been particularly positive (for example transmigration in Indonesia, Fearnside 1997) and forced relocation generates strong opposition and conflicts. In Mamberamo, temporal migration is a common coping strategy but villagers are reluctant to permanently shift the location of their villages. In Yoke, people feel they need to maintain a permanent presence to keep their settlement eligible for "official village" status. Adaptation programs will need to look for solutions that accommodate these concerns.

Adaptation interventions should also strive to find local solutions to current problems. For example, in Papasena, floods affect hunting and increase crop damage because wild animals move to the higher grounds where gardens are located. Food security is threatened by floods and climate change can aggravate this problem. Adaptation plans could increase food security now and under a future climate scenarios with techniques to reduce crop damage, e.g., traps for the animals, and alternative sources of food in case of shortage.

Adaptation interventions should also consider multiple changes affecting local people and their landscapes, rather than climatic variations only. Villagers said their livelihoods were more affected by political (decentralization), economic (activities from the private sector), and demographic changes than climatic variations. For example, decentralization has led to new institutions, e.g., multiplication of regencies, villages, and government representatives, and business developments that create new pressures on natural resources. These changes may be as unpredictable as changes in climate, but the ways local people cope with them provide valuable insight when looking at the implications for adaptation to climate change. One important observation is related to information flows in the region: as people regularly move along the Mamberamo River, they have a good knowledge of changes and impacts over the watershed. This information sharing could be valuable to future adaptation.

CONCLUSION

Eliciting traditional ecological knowledge and local perceptions can help to analyze extreme events such as floods and droughts, and their consequences. By comparing local and technical knowledge on climate, we have been able to identify gaps and areas of agreement. Although meteorological data from even a few weather stations can provide information on climate variability in isolated areas, such as Mamberamo, it cannot detect all relevant changes at the local village level. Local people on the other hand can provide more detailed information, based on their experience.

People in Mamberamo have experienced low climatic variability in general and this may partly explain why local people from the six villages of the study consider nonclimatic factors as having the biggest influence on their livelihoods. If adaptation programs seek local agreement and participation, their implementers will need to understand these wider issues. Villagers react to changes that they observe. To date this does not include "climate change" per se but in the future, the study of local variations in coping mechanisms to extreme climatic events and variability will help to determine what adaptation strategies need to be developed to address climate change.

Our examples illustrate a diversity of concerns and implications arising from climatic events. These examples included increased salinity of water supplies, crop loss due to floods, and reduced hunting success, each occurring in a different village. Although climate change is a global phenomenon, adaptation strategies must be specific to given locations and needs. Addressing local specificities will be a challenge, but any inflexible one-size-fits-all approach is likely to fail. Local engagement and diagnosis of problems encountered by local people will be fundamental to ensure success. Because TEK focuses on elements of significance for local people, it will play a primordial role in future plans for adaptation to climate change. Collaboration between TEK holders and scientists can generate new knowledge of high relevance to these plans.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5822

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LITERATURE CITED

Adger, W. N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. R. Nelson, L. O. Naess, J. Wolf, and A. Wreford. 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93:335-354.

Bandyopadhyay, S., L. Wang, and M. Wijnen. 2011. *Improving household survey instruments for understanding agricultural household adaptation to climate change: water stress and variability*. Living Standards Measurement Study - Integrated Surveys on Agriculture, Washington, D.C., USA.

Barnett, J., and S. O'Neill. 2010. Maladaptation. *Global Environmental Change* 20:211-213. http://dx.doi.org/10.1016/j.gloenvcha.2009.11.004

Berkes, F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10:1251-1262. http://dx.doi.org/10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2

Berkes, F., C. Folke, and M. Gadgil. 1995. Traditional ecological knowledge, biodiversity, resilience and sustainability. Pages 281-299 *in* C. A. Perrings, K.-G. Mäler, C. Folke, C. S. Holling, and B. O. Jansson, editors. *Biodiversity conservation*. Kluwer Academic, Dordrecht, The Netherlands.

Berkes, F., and D. Jolly. 2002. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology* 5(2): 18.

Boissière, M., and Y. Purwanto. 2007. The agricultural systems of Papua. Pages 1125-1148 *in* A. J. Marshall and B. M. Beehler, editors. *The ecology of Papua*. Periplus, Singapore.

Brockhaus, M., H. Djoudi, and B. Locatelli. 2013. Envisioning the future and learning from the past: adapting to a changing environment in northern Mali. *Environmental Science & Policy* 25:94-106. http://dx.doi.org/10.1016/j.envsci.2012.08.008

Bryan, E., T. T. Deressa, G. A. Gbetibouo, and C. Ringler. 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy* 12:413-426. http://dx.doi.org/10.1016/j.envsci.2008.11.002

Byg, A., and J. Salick. 2009. Local perspectives on a global phenomenon—climate change in Eastern Tibetan villages. *Global Environmental Change* 19:156-166. http://dx.doi.org/10.1016/j.gloenvcha.2009.01.010

Cooper, P. J. M., J. Dimes, K. P. C. Rao, B. Shapiro, B. Shiferaw, and S. Twomlow. 2008. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: an essential first step in adapting to future climate change? *Agriculture, Ecosystems & Environment* 126 (1-2):24-35. http://dx.doi.org/10.1016/j.agee.2008.01.007

Couzin, J. 2007. Opening doors to native knowledge. Scientific and local cultures seek common ground for tackling climate-change questions in the Arctic. *Science* 315:1518-1519. http://dx.doi.org/10.1126/science.315.5818.1518

Davies, S. 1993. Are coping strategies a cop out? *IDS Bulletin* 24(4):60-72. http://dx.doi.org/10.1111/j.1759-5436.1993.mp24004007.x

De Fretes, Y. 2007. Opportunities and challenges for doing conservation in Papua. Pages 1311-1326 *in* A. J. Marshall and B. M. Beehler, editors. *The ecology of Papua*. Periplus, Singapore.

Deressa, T. T., R. M. Hassan, C. Ringler, T. Alemu, and M. Yesuf. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19:248-255. http://dx.doi.org/10.1016/j.gloenvcha.2009.01.002

De Vries, J. 1988. Kwerba view of the supernatural world. *IRIAN* 16:1-16.

Eriksen, S., P. Aldunce, C. S. Bahinipati, R. D. A. Martins, J. I. Molefe, C. Nhemachena, K. Obrien, F. Olorunfemi, J. Park, L. Sygna, and and K. Ulsrud. 2011. When not every response to climate change is a good one: identifying principles for sustainable adaptation. *Climate and Development* 3(1):7-20. http://dx.doi.org/10.3763/cdev.2010.0060

Eriksen, S. H., K. Brown, and P. M. Kelly. 2005. The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania. *Geographical Journal* 171(4):287-305. http://dx.doi.org/10.1111/j.1475-4959.2005.00174.x

Eriksen, S., and J. A. Silva. 2009. The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. *Environmental Science & Policy* 12(1):33-52. http://dx.doi.org/10.1016/j.envsci.2008.10.007

Fabricius, C., C. Folke, G. Cundill, and L. Schultz. 2007. Powerless spectators, coping actors, and adaptive co-managers: a synthesis of the role of communities in ecosystem management. *Ecology and Society* 12(1): 9 [online] URL: http://www.ecologyandsociety.org/vol12/iss11/art29/

Fearnside, P. M. 1997. Transmigration in Indonesia: lessons from its environmental and social impacts. *Environmental Management* 21(4):553-570. http://dx.doi.org/10.1007/s002679900049

Fisher, M., M. Chaudhury, and B. McCusker. 2010. Do forests help rural households adapt to climate variability? Evidence from Southern Malawi. *World Development* 38:1241-1250. http://dx.doi.org/10.1016/j.worlddev.2010.03.005

Gbetibouo, G. A. 2009. *Understanding farmers' perceptions and adaptations to climate change and variability. The case of the Limpopo Basin, South Africa*. Discussion paper. International Food Policy Research Institute, Washington, D. C., USA.

Grothmann, T., and A. Patt. 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Global Environmental Change* 15:199-213. http://dx.doi.org/10.1016/j.gloenvcha.2005.01.002

Hansen, J., S. Marx, and E. Weber, editors. 2004. *The role of climate perceptions, expectations, and forecasts in farmer decision making: the Argentine Pampas and South Florida*. International Research Institute for Climate and Society, Palisades, New York, USA.

Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, and A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25:1965-1978. http://dx.doi.org/10.1002/joc.1276

Jacka J. 2009. Global averages, local extremes: the subtleties and complexities of climate change in Papua New Guinea. Pages 197-208 in S. A. Crate and M. Nuttall, editors. *Anthropology and climate change. From encounters to actions.* Left Coast Press, Walnut Creek, California, USA.

Johns, R. J., G. A. Shea, and P. Puradyatmika. 2007. Lowland swamp and peat vegetation of Papua. Pages 910-944 *in* A. J. Marshall and B. M. Beehler, editors. *The ecology of Papua*. Periplus, Singapore.

Liswanti, N., D. Sheil, I. Basuki, M. Padmanaba, and G. Mulcahy. 2011. Falling back on forests: how forest-dwelling people cope with catastrophe in a changing landscape. *International Forestry Review* 13:442-455. http://dx.doi.org/10.1505/146554811798811326

Maddison, D. 2007. *The perception of and adaptation to climate change in Africa*. Policy Research Working Paper. The World Bank, Washington, D.C., USA.

McCarthy, N. 2011. *Understanding agricultural households' adaptation to climate change and implications for mitigation: land management and investment options*. Living Standards Measurement Study - Integrated Surveys on Agriculture, LEAD Analytics, Inc., Washington, D.C., USA.

Mitchell, T. D., T. R. Carter, P. D. Jones, M. Hulme, and M. New. 2004. *A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100)*. Tyndall Centre for Climate Change Research, Norwich, UK.

Mitchell, T. D., and P. D. Jones. 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology* 25:693-712. http://dx.doi.org/10.1002/joc.1181

Morton, J. F. 2007. The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences* 104:19680-19685. http://dx.doi.org/10.1073/pnas.0701855104

Mubaya, C. P., J. Njukib, E. P. Mutsvangwa, F. T. Mugabe, and D. Nanja. 2012. Climate variability and change or multiple stressors? Farmer perceptions regarding threats to livelihoods in Zimbabwe and Zambia. *Journal of Environmental Management* 102:9-17. http://dx.doi.org/10.1016/j.jenvman.2012.02.005

O'Brien, K., T. Quinlan, and G. Ziervogel. 2009. Vulnerability interventions in the context of multiple stressors: lessons from the Southern Africa Vulnerability Initiative (SAVI). *Environmental Science & Policy* 12:23-32. http://dx.doi.org/10.1016/j.envsci.2008.10.008

Oosterwal, G. 2007. Murumarew: a dual organized village on the Mamberamo, West Irian. Pages 157-188 *in* Koentjaraningrat, editor. *Villages in Indonesia.* First Equinox Edition. Equinox, Singapore.

Orlove, B. S., J. C. H. Chiang, and M. A. Cane. 2000. Forecasting Andean rainfall and crop yield from the influence of El Nino on Pleiades visibility. *Nature* 403:68-71. http://dx.doi.org/10.1038/47456

Osbahr, H., C. Twyman, W. N. Adger, and D. S. G. Thomas. 2008. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum* 39:1951-1964. http://dx.doi.org/10.1016/j.geoforum.2008.07.010

Polhemus, D. A., and G. R. Allen. 2007. Freshwater biogeography. Pages 207-245 *in* A. J. Marshall and B. M. Beehler, editors. *The ecology of Papua*. Periplus, Singapore.

Pramova, E., B. Locatelli, H. Djoudi, O. A. Somorin. 2012. Forests and trees for social adaptation to climate variability and change. Wiley Interdisciplinary Reviews: *Climate Change* 3:581-596. http://dx.doi.org/10.1002/wcc.195

Ramirez-Villegas, J., and A. Challinor. 2012. Assessing relevant climate data for agricultural applications. *Agricultural and Forest Meteorology* 161:26-45. http://dx.doi.org/10.1016/j.agrformet.2012.03.015

Ravera, F., D. Tarrasón, and E. Simelton. 2011. Envisioning adaptive strategies to change: participatory scenarios for agropastoral semiarid systems in Nicaragua. *Ecology and Society* 16(1): 20. [online] URL: http://www.ecologyandsociety.org/vol16/iss1/art20/

Reid, P., and C. Vogel. 2006. Living and responding to multiple stressors in South Africa – glimpses from KwaZulu-Natal. *Global Environmental Change* 16:195-206. http://dx.doi.org/10.1016/j.gloenvcha.2006.01.003

Roncoli, C., K. Ingram, P. Kirshen. 2001. The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. *Climate Research* 19(2):119-132. http://dx.doi.org/10.3354/cr019119

Sánchez-Cortés, M. S., and E. L. Chavero. 2011. Indigenous perception of changes in climate variability and its relationship with agriculture in a Zoque community of Chiapas, Mexico. *Climatic Change* 107:363-389. http://dx.doi.org/10.1007/s10584-010-9972-9

Saroar, M. M., and J. K. Routray. 2012. Impacts of climatic disasters in coastal Bangladesh: why does private adaptive capacity differ? *Regional Environmental Change* 12:169-190. http://dx.doi.org/10.1007/s10113-011-0247-4

Shackleton, S. E., and C. M. Shackleton. 2012. Linking poverty, HIV/AIDS and climate change to human and ecosystem vulnerability in southern Africa: consequences for livelihoods and sustainable ecosystem management. *International Journal of Sustainable Development & World Ecology* 19:275-286. http://dx.doi.org/10.1080/13504509.2011.641039

Sheil, D., and A. Lawrence. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends in Ecology and Evolution* 19:634-638. http://dx.doi.org/10.1016/j.tree.2004.09.019

Sheil, D., R. K. Puri, I. Basuki, M. van Heist, M. Wan, N. Liswanti, Rukmiyati, M. A. Sardjono, I. Samsoedin, K. Sidiyasa, Chrisandini, E. Permana, E. M. Angi, F. Gatzweiler, B. Johnson, and A. Wijaya. 2002. *Exploring biological diversity, environment and local people's perspectives in forest landscapes: methods for a multidisciplinary landscape assessment*. CIFOR, Bogor, Indonesia.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16 (3):282-292. http://dx.doi.org/10.1016/j.gloenvcha.2006.03.008

Takasaki, Y., B. L. Barham, and O. T. Coomes. 2004. Risk coping strategies in tropical forests: floods, illnesses, and resource extraction. *Environment and Development Economics* 9:203-224. http://dx.doi.org/10.1017/S1355770X03001232

Thomas, D. S. G., C. Twyman, H. Osbahr, and B. Hewitson. 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change* 83:301-322. http://dx.doi.org/10.1007/s10584-006-9205-4

Trenberth, K. E., P. D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J. A. Renwick, M. Rusticucci, B. Soden and P. Zhai. 2007. Observations: surface and atmospheric climate change. Page 235-336 *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. *The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

van Heist, M., D. Sheil, I. Rachman, P. Gusbager, C. O. Raweyai, and H. S. M. Yoteni. 2010. The forests and related vegetation of Kwerba, on the Foja Foothills, Mamberamo, Papua (Indonesian New Guinea). *Blumea* 55:153-161. http://dx.doi.org/10.3767/000651910X526889

Vedwan, N., and R. E. Rhoades. 2001. Climate change in the Western Himalayas of India: a study of local perception and response. *Climate Research* 19:109-117. http://dx.doi.org/10.3354/cr019109

Vignola, R., T. Koellner, R. W. Scholz, and T. L. McDaniels. 2010. Decision-making by farmers regarding ecosystem services: factors affecting soil conservation efforts in Costa Rica. *Land Use Policy* 27:1132-1142. http://dx.doi.org/10.1016/j.landusepol.2010.03.003

West, C. T., and M. Vásquez-León. 2003. Testing farmers' perceptions of climate variability: a case study from the Sulphur Springs Valley, Arizona. Pages 233-250 *in* S. Strauss and B. Orlove, editors. *Weather, climate, culture.* Berg, Oxford, UK.